Claims

1. A method of deriving a 3D representation (30) of at least part of an object (3) from correlated overlapping 2D images of the object acquired from different spaced apart viewpoints (CM, CM') relative to the object, the separation between the viewpoints not being precisely known, the method comprising the step of digitally processing the 2D images to form a 3D representation which extends in a simulated 3D space in dependence upon both the mutual offset between correspondences of the respective 2D images and a scaling variable, the scaling variable being representative of the separation between the viewpoints at which the 2D images were acquired.

2. A method of deriving a 3D representation (30) of at least part of an object (3) from a 2D image thereof, comprising the steps of illuminating the object with structured projected optical radiation, acquiring a 2D image (I1) of the illuminated object, correlating the 2D image with rays of the structured optical radiation, and digitally processing the 2D image to form a 3D representation which extends in a simulated 3D space in dependence upon both the correlation and a scaling variable, the scaling variable being representative of the separation between a location from which the structured optical radiation is projected and the viewpoint at which the 2D image is acquired.

3. A method as claimed in claim 1 ~~or claim 2~~ wherein a view of the representation (30) in the simulated 3D space is displayed and the scaling variable is entered by a user.

4. A method as claimed in claim 1 ~~any preceding claim,~~ comprising the step of acquiring overlapping 2D images from a camera (CM) which is moved relative to the object, the net movement of the camera not being fully constrained.

5. A method as claimed in claim 4 wherein the respective orientations of the camera (CM) at the different viewpoints relative to a reference frame which is fixed with respect to the object (3) differ by less than 45 degrees.

6. A method as claimed in claim 5 wherein the difference between said respective orientations of the camera (CM) is less than 30 degrees.

7. A method as claimed in claim 6 wherein the difference between said respective orientations of the camera (CM) is less than 10 degrees.

8. A method as claimed in claim 4 ~~any of claims 4 to 7~~ wherein the 2D images are acquired by a hand-held camera (CM).

9. A method as claimed in claim 1 ~~any preceding claim~~ wherein at least one 2D image is acquired by a camera (CM) whose orientation is determined from an output signal of an inertial sensor (G).

10. A method as claimed in claim 1 ~~any preceding claim~~ wherein the 3D representation (30) is generated by projections from positions on a straight line (V) in simulated 3D space which corresponds to the straight line joining respective perspective centres of said 2D images or joining respective perspective centres of said structured optical radiation and 2D image of the illuminated object (3).

11. A method as claimed in claim 10 wherein said straight line (V) in simulated 3D space is determined from a pencil of projections from correspondences of aligned 2D images (I1, I2).

12. A method as claimed in claim 10 wherein said straight line in simulated 3D space (V) is determined from the intersection of planes ($O_C P1 O_P$, $O_C P2 O_P$) defined by at least one perspective centre (O_C, O_P) and at least two pairs of correspondences (PQ) between acquired 2D images (I1, I2).

13. A method as claimed in claim 1 ~~any preceding claim~~ wherein said scaling variable is varied by the user to enable the 3D representation (R1) to be fitted to another, similarly derived 3D representation (R2).

14. A method as claimed in claim 1 ~~any preceding claim~~ wherein the 3D representation (30) is generated from the intersection of respective projections from spaced apart perspective centres (O_C, O_P), the perspective centres being derived from the mutual offset between a first pair of correspondences (PQ) between respective 2D images (I1, I2) and from a further mutual offset between a second pair of correspondences between respective 2D images, further pairs of correspondences are derived from a search constrained by the above perspective centre determination and the 3D

representation of the object is derived from the further pairs of correspondences and the projections.

15. A method as claimed in claim 14 wherein said calculation is performed on fewer than one thousand pairs of image correspondences (PQ).

16. A method as claimed in claim 15 wherein said calculation is performed on fewer than one hundred pairs of image correspondences (PQ).

17. A method as claimed in claim 16 wherein said calculation is performed on fewer than fifty pairs of image correspondences (PQ).

18. A method as claimed in claim 17 wherein said calculation is performed on eight or fewer pairs of image correspondences (PQ).

19. A method as claimed in claim 18 wherein said calculation is performed on two or three or four pairs of image correspondences (PQ).

20. A method as claimed in ~~any preceding claim~~ comprising the step of repeating the method of claim 1 ~~or claim 2~~ by digitally processing further 2D images of the object acquired from different further viewpoints (CMA, CMA') to form a further 3D representation, the first-mentioned 3D representation and the further 3D representation being combined by manipulations in a simulated 3D space involving one or more of rotation and translation, any remaining discrepancies between the 3D recpresentations optionally being reduced or eliminated by scaling one 3D representation relative to the other along at least one axis.

21. A method as claimed in claim 20 wherein at least two of the 3D representations (R1, R2) are simultaneously displayed on screen (5) and their manipulations are performed in response to commands entered by a user.

22. A method as claimed in claim 21 wherein the manipulations of the 3D representations (R1, R2) are performed under the control of a computer pointing device (6) operated by the user.

23. A method as claimed in claim 20 ~~any of claims 20 to 22~~ wherein a distortion parameter is

entered by the user and applied to said first-mentioned and/or said further 3D representation.

24. A method as claimed in claim 23 wherein an initial 3D representation (30', Figure 9) in simulated 3D space is generated by intersecting projections from spaced apart perspective centres, and the initial 3D representation is rotated whilst constraining the points of the initial 3D representation which are generated from the intersecting projections to lie on the projections of those features from their respective perspective centres, thereby forming a further 3D representation (30C, Figure 9).

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25. A method as claimed in ~~any of claims 20 to 24~~ wherein a further parameter indicative of curvature of field is entered by the user and used to adjust the curvature of field of said first-mentioned and/or said further 3D representation.

26. Image processing apparatus for deriving a 3D representation of at least part of an object from correlated overlapping 2D images of the object acquired from different spaced apart viewpoints relative to the object, the apparatus comprising image processing means (4) which is arranged to digitally process the 2D images to form a 3D representation (30) which extends in a simulated 3D space in dependence upon both the mutual offset between correspondences of the respective 2D images and a scaling variable, the scaling variable being representative of the separation between the viewpoints (CM, CM') at which the 2D images were acquired.

27. Image processing apparatus for deriving a 3D representation of at least part of an object from a 2D image of the illuminated object, the object being illuminated with structured optical radiation projected from a location (O_P) spaced apart from the viewpoint (O_C) at which the 2D image is acquired, the 2D image being correlated with the structured radiation, the apparatus comprising digital processing means (4) arranged to form a 3D representation which extends in a simulated 3D space in dependence upon both the correlation and a scaling variable, the scaling variable being representative of the separation between the location from which the structured optical radiation is projected and the viewpoint at which the 2D image is acquired.

28. Apparatus as claimed in claim 26 ~~or claim 27~~ comprising display means (5)

arranged to display a view of the representation in simulated 3D space, the size of the displayed representation being dependent upon the value of the scaling variable .

29. Image processing apparatus as claimed in claim 28, further comprising a camera (CM) whose position and/or orientation are not fully constrained with respect to the frame of the object, the camera being arranged to acquire said 2D images.

30. Apparatus according to claim 29 comprising inertial sensor means (G) arranged to determine the orientation of the camera relative to the object at the time of acquisition of said 2D images.

31. Apparatus as claimed in claim 26 ~~any of claims 26 to 30~~ which is arranged to generate the 3D representation from the intersection of respective projections from spaced apart perspective centres (pr1, Pr2/pr2'), the perspective centres being derived from the mutual offset between a first pair of correspondences between respective 2D images and from a further mutual offset between a second pair of correspondences between respective 2D images, to derive further pairs of correspondences from a search constrained by the above perspective centre determination and to derive the 3D representation of the object from the further pairs of correspondences and the projections.

32. Apparatus as claimed in claim 26 ~~any of claims 26 to 31~~ which is arranged to derive a further 3D representation from further intersections of further projections from further perspective centres (CMA.m CMA'), the apparatus including combining means (4) arranged to combine the first-mentioned 3D representation and the further 3D representation by manipulations in a simulated 3D space involving one or more of rotation and translation, the apparatus further comprising scaling means (BN, W1, W2) arranged to reduce or eliminate any remaining discrepancies between the 3D representations by scaling one 3D representation relative to the other along at least one axis.

33. Apparatus as claimed in claim 32 which is arranged to display both 3D representations (R1, R2) simultaneously and to manipulate them in simulated 3D space in response to commands entered by a user.

34. Apparatus as claimed in claim 32 ~~or claim 33~~ which is arranged to correct

distortion of said first-mentioned and/or said further 3D representation resulting from an incorrect or incomplete calculation of a said perspective centre.

35. Apparatus as claimed in claim 32 ~~any of claims 32 to 34~~ which is arranged to correct the curvature of field of said first-mentioned and/or said further 3D representation (30' Figure 9) resulting from an incorrect or incomplete calculation of a said perspective centre (pr2' - Figure 9).

36. A method of determining the motion of a camera (CM) relative to an object (3) in the field of view of the camera comprising the steps of projecting the paths (L1, L2, L3 - Figure 4) of features of the image of the object to a common vanishing point (VP) and determining the vector (V) between the perspective centre of the camera (O) and this vanishing point.

37. Apparatus for determining the motion of a camera relative to an object in the field of view of the camera comprising means (4) for projecting the paths (L1, L2, L3 - Figure 4) of features of the image of the object to a common vanishing point and means for determining the vector (V) between the perspective centre (O) of the camera and this vanishing point.

38. A method of generating a 3D reconstruction of an object (3) comprising the steps of projecting images of the object acquired by mutually aligned cameras (CM, CM') into simulated 3D space from aligned virtual projectors (pr1, pr2), the separation of the virtual projectors being variable by the user.

39. Apparatus for generating a 3D reconstruction of an object (3) comprising two aligned virtual projector means (pr1, pr2) arranged to project images of the object acquired by mutually aligned cameras into simulated 3D space, the separation of the virtual projectors being variable by the user.

40. Apparatus for generating a 3D representation of at least part of an object (3) from an object image (I1) of the projection of structured optical radiation onto the object surface and from at least one calibration image (I2) of the projection of the structured optical radiation onto a surface displaced from the object surface, the apparatus comprising image processing means (4) arranged to generate correspondences (PQ) between at least one calibration image and the object image

and optionally a further calibration image, and reconstruction processing means arranged to simulate a first projection of the object image and a second projection linking respective correspondences of at least two of the correlated images and to derive said 3D representation from the mutual intersections of the first and second projections.

41. Apparatus as claimed in claim 40 wherein the first and second projections are from a baseline (V) linking an origin of the structured optical radiation (OP) and a perspective centre (OC) associated with the images (I1, I2), the reconstruction processing means (4) being arranged to derive said baseline from the correlation (PQ).

42. Apparatus as claimed in claim 40 ~~or claim 41~~ wherein the image processing means (4) is arranged to correlate two or more calibration images and to determine the spacing between origins of the first and second projections (OC, OP) in dependence upon both the correlation of the two or more calibration images and input or stored metric information associated with the calibration .

43. Apparatus as claimed in claim 40 ~~any of claims 40 to 42~~ further comprising projector means (PR) arranged to project the structured optical radiation onto the object surface and at least one calibration surface (T1, T2).

44. Apparatus as claimed in claim 40 ~~any of claims 40 to 42~~ further comprising a camera (CM) arranged to acquire the object image (I1) and at least one calibration image (I2).

45. Apparatus as claimed in claim 40 ~~any of claims 40 to 42~~ further comprising at least one calibration target (T1, T2) which in use is illuminated by the structured radiation.

46. Apparatus as claimed in claim 40 ~~any of claims 40 to 42~~ wherein the image processing means (4) is arranged to correlate pixels in one of said images (I1) with corresponding locations in the other of said images (I2) by comparing the local radiometric distributions associated with said pixels and locations respectively.

47. Apparatus as claimed in claim 46 wherein the image processing means (4) is arranged to allow a radiometric and/or geometric distortion during the correlation

process.

48. A method of generating a 3D representation of an object (3) from an object image (I1) of the projection of structured optical radiation onto the object surface and from at least one calibration image (I2) of the projection of the structured optical radiation onto a surface displaced from the object surface, the method comprising the steps of:

i) correlating at least one calibration image with the object image and optionally with a further calibration image;

ii) simulating a first projection of the object image and a second projection of the structured optical radiation, and

iii) deriving said 3D representation from the mutual intersections of the first and second projections.

49. A method as claimed in claim 48 wherein the first and second projections are from a baseline (V) linking an origin of the structured optical radiation (OP) and a perspective centre (OC) associated with the image respectively, said baseline being derived from two or more pairs of image correspondences (PQ).

50. A method as claimed in claim 48 ~~or claim 49~~ wherein two or more calibration images are correlated and the spacing between origins of the first and second projections (OC, OP) is determined in dependence upon both the correlation of the two or more calibration images and input or stored metric information associated with the calibration images.

51. A method as claimed in claim 48 ~~any of claims 48 to 50~~ wherein regions (R) of said images (I1, I2) are correlated by comparing the local radiometric and/or colorimetric distributions associated with said regions.

52. A method as claimed in claim 51 wherein a radiometric and/or geometric distortion is allowed between potentially corresponding regions (R).

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